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MUNICIPAL SOLID WASTE QUANTIFICATION AND CHARACTERIZATION IN BANYUWANGI, INDONESIA

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ABSTRACT

Aim: This study aims to identify the characteristics and generation of municipal solid waste (MSW) in Banyuwangi. **Methodology and Results:** The solid waste characterization was carried out in two areas in Banyuwangi, referring to the Indonesian National Standard (*Standar Nasional Indonesia*/SNI) 19-3964-1995. The results show that the highest composition is organics of 36% (39% from households/HSW and 35.35% from Non-HSW). The highest solid waste (SW) generation from industrial areas and train station are 0.61 and 1.38 kg/population.day, respectively, while the SW density from the bus station is 375.46 kg/m^3. The weight, volume, and density of household solid waste (HSW) are 0.17 kg/population.day, 2.02 L/population.day, and 81.07 kg/m^3, respectively. The population of Zone 1 and Zone 2 is 142.054 in 2016, generating 8,814 tons of HSW per year (tpy). **Conclusion, significance and impact study:** The main MSW compositions in Banyuwangi are organics (36%), plastics (17.20%), and papers (15.78%). Household solid waste generation in Banyuwangi reaches 8.8 tons per year with the primary compositions of 39% organics, 18.92% residues, 18.4% papers, and 14.4% plastics. The highest number of residue defines that 81% of solid waste can be recycled.

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- Municipal Solid Waste
- Volume
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1. INTRODUCTION

Municipal Solid Waste (MSW) is generated from various sources such as household activities, commercial areas, and public facilities. It has become a real problem in many cities including Banyuwangi Regency due to the increasing population and its poor management (planning, monitoring, and evaluation). In 2014, the total MSW production in Indonesia was 190,000 metric tons/day (Sudibyo, 2017). However, in a larger scale, it is predicted that MSW generation in Asia will reach 1.8 million tons or 5.2 million m^3 per day by 2025, which would result to a huge cost of approximately US$50 billion (The World Bank, 1999). In most developing countries, 55 – 80% MSW is generated from household activities, which is followed by the market (commercial areas) by 10 – 30%. The characteristics of waste products are naturally varied, depending on the physical and chemical properties of its original sources, thereby the treatment difficult and time consuming.

On the average, city inhabitants produce waste three times larger than the rural regions. An instance is Jeddah which is dominated by 48% organics and 21% paper (Hakami, 2015). Crete (Greece), also indicates biodegradable dominance of 78%, while East Java primarily consists of 60% organic waste (OW) (Verstappen, *et al.*, 2016).

One basic step to overcome this problem is to identify the generation and composition of MSW by determining suitable management and treatments techniques such as recycling, designing treatment apparatus, as well as determining the right physical, chemical, biological, and thermal properties with local, regional, and national standards (Sfeir, 2011). However, several developing countries are deemed unsuccessful in handling their MSW due to poor resources management.

This research, therefore aims to identify recyclable quantity or residue dumped into the landfill. The results of this study furthermore are crucial to support government policy of MSW management and useful as a basis for the municipality to establish a solid-waste-to-energy conversion facility.

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2. RESEARCH METHODOLOGY

2.1 Area of Study

Banyuwangi Regency is the largest district in East Java Province. It is located at 7°43'–8°46' South Latitude and 113°53' – 114°38' East Longitude, covering an area of 5,782.50 km^2. It consists of 24 districts with a total population of 1,574,778 people with 315,218 living in the urban area (Banyuwangi, Giri, Kabat, Kalipuro, Glagah) and 1,259,520 in the countryside (Banyuwangi in Figures, 2013). The population density is 3,561 people per km^2 with total inhabitants of 107,305. The topography of its western and northern parts is generally mountainous, while the southern part is mostly lowland.

The existing state of solid waste service is managed by the Environmental Office located in Banyuwangi, Kalipuro, Giri, Glagah, Rogojampi, Genteng, Srono, Muncar, and Gambiran Districts.

2.2 Sampling Location

Solid waste composition surveys were conducted in three types of residential areas (high, average, and low income) and public facilities such as hospital, mall, restaurant, industry, traditional market, station, terminal, office, hotel, and school. Figure 1 below depicts SW collection from various sources.

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(a) (b) (c) (d)

Figure 1 SW sampling in several locations of a) office, b) church, c) low income households, and d) 2-star hotel

The following formula is used to count the sample:

$$S = Cd \sqrt{Ps} \quad (1)$$

where: Cd = 0.5 = average city/small/district; and Ps = Population.

Table 1 Sampling population

No	Facility	Population	Sampling
1.	Traditional Market		
2.	Industry	20	2 for Zone 1 and Zone 2
3.	Bus station	1	1
4.	Station	1	1
5.	Offices	1	1
6.	Mall	1	1
7.	Hotel	68	8 (2 for Zone 1 and Zone 2)
8.	Mosque	724	27 (2 for Zone 1 and Zone 2)
9.	Church	56	7 (2 for Zone 1 and Zone 2)
10.	Temple	124	11 (2 for Zone 1 and Zone 2)
11.	Monastery	31	6 (1, choose the largest)
12.	Hospital	8	3 (2 for private and public hospital)
13.	Community Health Center	-	1
14.	Kindergarten	289	17 (2 for Zone 1 and Zone 2)
15.	Elementary School	301	17 (2 for Zone 1 and Zone 2)
16.	Junior High School	69	8 (2 for Zone 1 and Zone 2)
17.	High School	24	5 (2 for Zone 1 and Zone 2)
18.	High Income House	100	25
19.	Middle Income House	120	30
20.	Low Income House	180	45

**Zone I: Districts of Wongsorejo, Kalipuro, Licin, Glagah, Giri, and Banyuwangi*
Zone II: Districts of Rogojampi, Srono, Muncar, and Genteng

2.2.1 Sampling Method of Solid Waste Composition

The aggregation of solid waste from both household and public facilities refers to SNI (National Standard Method) 19-3964-1995. It was collected from the aforementioned sources concurrently for 7 (seven) days in 100 kg samples, after which it was sorted, weighted, and compressed (SNI, 1995) into these categories:

- Organic: leaves and yard waste
- Hazardous waste: batteries, sanitary napkins, diapers, medicine, used medical equipment
- Paper: any kinds of books, magazines, packaging materials, newspapers, and cardboard
- Plastic: PET, PVC, LDPE, HDPE, etc.
- Metal: tin can, aluminum
- Rubber: tires of any kind and color
- Textile: fabrics
- Glass: of any kind color
- Residue/others: building debris and demolition waste
- Tree: branches, twigs, woodcuts, stems (part of hard trees)

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- Food waste: any processed food waste

$$SW\ Composition = a/(100\ kg)\ x\ 100\% \quad (2)$$

$$\%\ SW = (a\ x\ 100\%)/(Total\ Weight\ of\ SW) \quad (3)$$

$$SW\ Composition\ Volume = (a\ x\ 100\%)/(SW\ Density) \quad (4)$$

Where: a = weight of each SW category (kg).

2.2.2 Sampling Method of Solid Waste Density

The solid waste generation was determined using the crossroad theory to derive an amount of 200 lb or 100 kg (Tchobanoglous et al., 1993). The box dimension for SW sample is (47x28x29) cm, and it weighs 2.25 kg. However, its total weight is measured as x kg, whereas vs represent the SW volume after compressing the box.

$$Solid\ Waste\ in\ Box\ Volume\ (B.V) = length\ x\ width\ x\ height \quad (5)$$

$$Solid\ Waste\ in\ Box\ Volume\ (B.V) = x/Vs \quad (6)$$

3. RESULTS AND DISCUSSION

Based on the SNI methods, the analyses of MSW composition and generation are briefly described in the following chapters.

3.1 Solid Waste Composition

The solid waste characterization from each source is grouped into two types, namely household (HSW) and non-household (non-HSW). Figure 2 below shows the total composition of MSW in Banyuwangi Regency. The largest composition is organics (36%), followed by residues (20.33%), plastics (17.20%), and paper (15.78%).

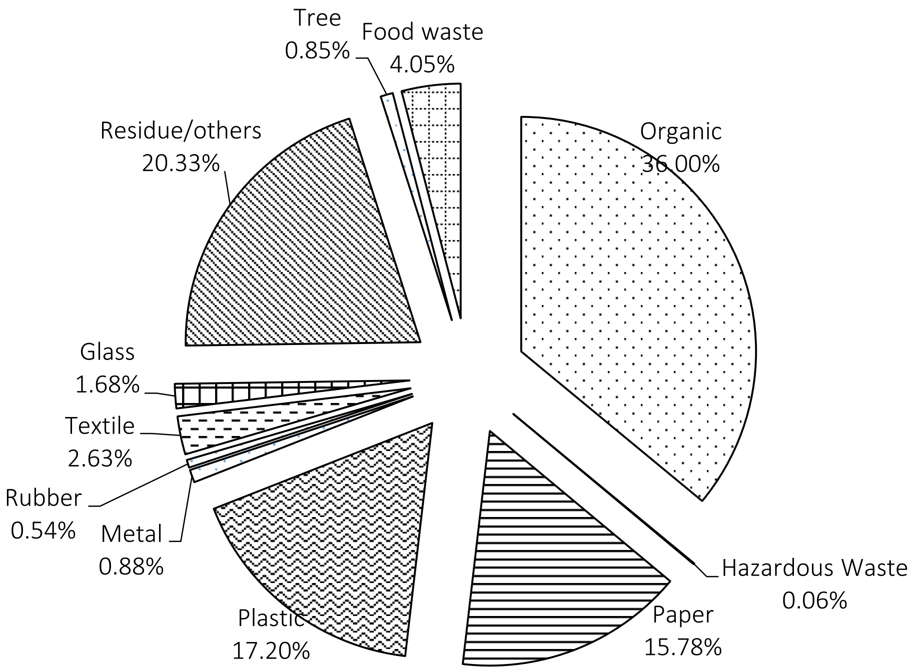

Figure 2 Total SW composition in Banyuwangi Regency

Both HSW and Non-HSW contain 39% and 35.35% organic compounds respectively (Figure 3). This finding is in line with the previous research that stated household solid waste (HSW) mostly consists of plastics, paper, glass, metals, organics, wood, and others (Hakami, 2015). Most developing and least developed countries contain 40 – 85% organic matters in their urban waste stream (The World Bank, 1999). The residue composition in this research is quite high in both groups with an average of 20%. Plastic substances in Non-HSW is higher than HSW, while paper composition in HSW is higher than those found in Non-HSW. Both groups contain recyclable materials comprising paper, plastics, and metal. Its compositions in HSW are 18.40%, 14.42%, and 0.88%, respectively, while for Non-HSW of 15.29%, 18.36%, and 0.86%.

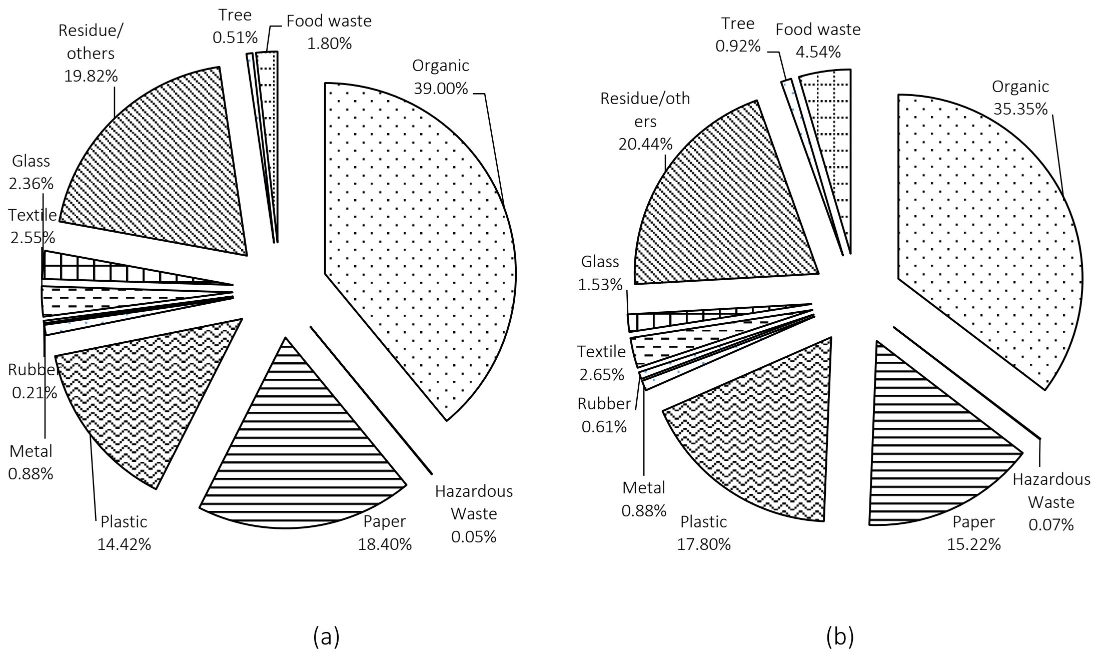

Figure 3 Solid waste composition in Banyuwangi Regency comprising a) Household SW, and b) Non-household SW

The detailed composition of each Non-HSW source can be seen in Figure 4 below. Its sources are the traditional market, industry, bus station, station, offices, mall, hotel, worship place, hospital, and school. The number in this research is greater than those in other regions such as in Surabaya where sorting categories of metals, paper, plastics, textiles, wood, food waste, yard waste, and glass are applied (Arafat and Jijakli, 2013). The percentage of the total amount of MSW depends on certain factors such asthe hazardous waste composition from hospitals due to specific activities producing harmful or infectious residue. Other affecting factors are the season, lifestyle, geographic condition, demographic profile, and local legislative influence (Sfeir et al., 2016). The highest amount of organics, textile, and food waste in the percentages of 34.58%, 76.21%, and 74.15% respectively, came from the traditional market, while paper, plastics, and rubber of 35.58%, 29.65%, and 32.73% were generated from school.

Minor compositions of metal (39.39%) and wood (45.67%) were yielded from worship places and industries. Therefore, waste-to-energy operations have the advantages of resource utilization and the minimization of landfill disposal (Arafat, *et al.*, 2013). In this research, the highest amount of residue that cannot be recycled and must be disposed was generated from school with a percentage of 46.84%.

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In this research, it is found that the residue composition is quite high compared with other substances.

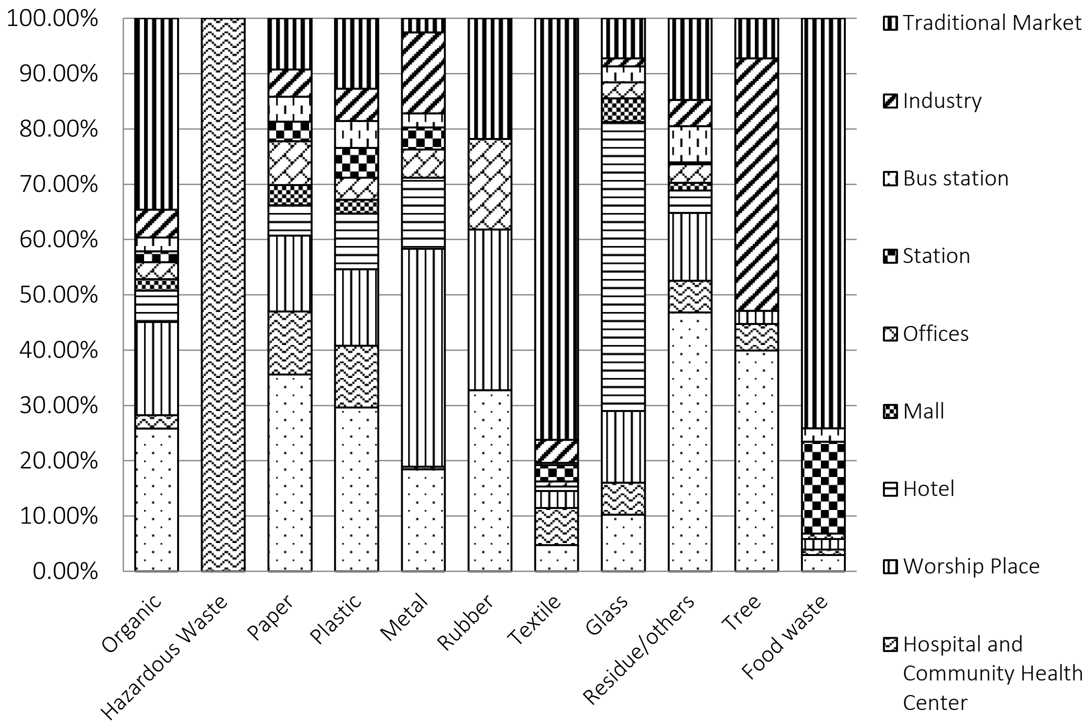

Figure 4 Solid waste composition from each source in Banyuwangi Regency

3.2 Solid Waste Quantification

Table 2 showed the results from SW generation for 7 (seven) consecutive days. The largest weight, volume, and density are yielded by the industry of 0.61 kg/population.day, the station source of 1.38 kg/population.day, and the bus station of 375.46 kg/m^3, respectively. SW generation in Banyuwangi is higher than in Zarqa, and Jordan compared to other cities in a developing country which produces 0.9 kg/population.day (Younes, *et al.*, 2013). The weight, volume, and density of HSW are 0.17 kg/population.day, 2.02 L/population.day, and 81.07 kg/m^3 respectively.

The volume needs to be addressed by providing ample-sized bins, scheduling the rotation numbers, and managing the landfill. The average MSW volume in this research is 1.59 liter/population.day, while the average density is 108.60 kg/m^3 which in line with the range of 60 – 120 kg/m^3 (Weiner, 2003) and varies based on the humidity, season, location, and other

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variables. The density of SW will affect the compaction factor that is essential in landfill planning as a part of its management.

Table 2 Solid waste generation in Banyuwangi

No.	Source	Weight (kg/pop.day)	SD	Volume (L/pop.day)	SD	Density (kg/m^3)	SD
1	Household	0.17	0.08	2.02	0.42	81.07	0.38
2	Traditional market	0.12	0.07	0.51	0.015	242.82	0.01
3	Industry	0.61	0.39	4.53	0.19	80.14	
4	Bus station	0.04	0.0019	0.01	0.0028	375.46	0.94
5	Train station	0.15	0.074	1.38	0.41	106.34	0.34
6	Offices	0.077	0.053	0.75	0.16	0.61	0.13
7	Mall	0.17	0.074	3.5	0.69	49.12	0.23
8	Hotel	0.06	0.038	0.58	0.14	97.26	0.0047
9	Worship place	0.16	0.14	1.95	0.47	71.29	0.43
10	Hospital and community health center	0.001	0.00039	2.15	0.32	0.37	0.14
11	School	0.013	0.01	0.144	0.08	90.13	0.47
Average		0.14	0.08	1.59	0.26	108.60	0.28

**SD : Standard Deviation*

With a population of 142,054 in 2016 (both Zone 1 and Zone 2), Banyuwangi generates 8.814 tons of HSW per year (tpy). This number is lower than the Columbia District as a part of a developing country which generates 895,020 tpy (low peak) to 930,471 tpy (high peak) in 2011 for a population of 654,708 (Department of Public Works of Columbia District, 2011).

4. CONCLUSION

The primary compositions of municipal solid waste in Banyuwangi are organics (36%), plastics (17.20%), and paper (15.78%). Household solid waste generation in this region reaches 8.8 tons per year with the main constituents of organics (39%), residue (18.92%), paper (18.4%), and plastics (14.4%). The aforementioned number of residue defines that 81% of solid waste can be recycled therefore waste volume can be reduced by around this percentage using this technique prior to the final disposal.

5. ACKNOWLEDGEMENT

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